(12) UK Patent Application (19) GB (11) 2 251 492 (13) A

(43) Date of A publication 08.07.1992

(21) Application No 9122732.2

(22) Date of filing 25.10.1991

(30) Priority data
(31) 9023422 (32) 27.10.1990 (33) GB

(71) Applicant
Air Technology Limited

(Incorporated in the United Kingdom)

Unit 6, Falcon Street, Loughborough, Leics, LE11 1EH, United Kingdom

(72) Inventors
David Friend
Anthony White

(74) Agent and/or Address for Service
E N Lewis & Taylor
144 New Walk, Leicester, LE1 7JA, United Kingdom

(51) INT CL⁵
F04B 51/00, G01M 19/00

(52) UK CL (Edition K)
G1N NAAJ N3S1A N4C N4E N7A1 N7C N7F
U1S S2004 S2180

(56) Documents cited
EP 0100210 A2 US 4584876 A

(58) Field of search
UK CL (Edition K) G1N NAAJ
INT CL⁵ F04B 51/00, G01M 19/00

(54) Compressor monitoring system

(57) A system for monitoring selected parameters of a dual cylinder air compressor has sensors (12, 42, 82, 102) for monitoring the input and output air temperatures of the low pressure and high pressure cylinders and pressure sensors (62, 70) for monitoring the air pressure between the cylinders and the output air pressure. The resulting signals from the sensors are operated on by various function generators to provide signals which are indicative of the efficiency or health of the individual cylinders and also of the overall compressor.

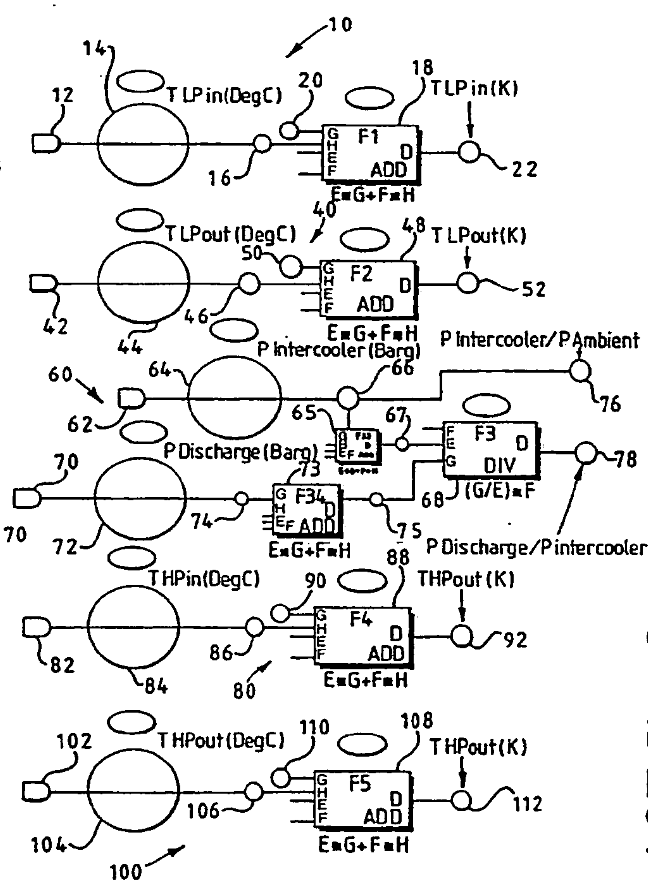


FIG 1

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

GB 2 251 492 A

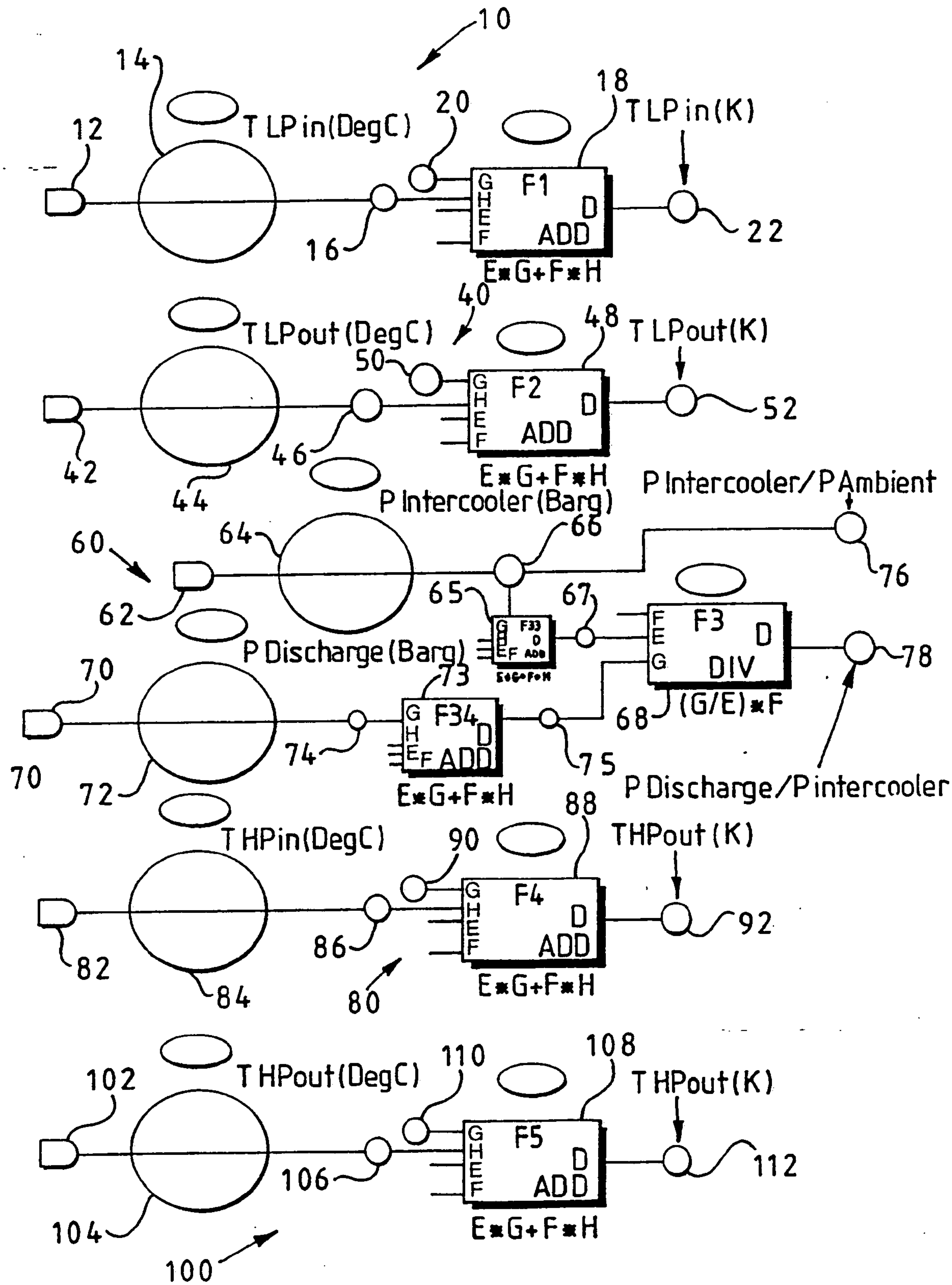
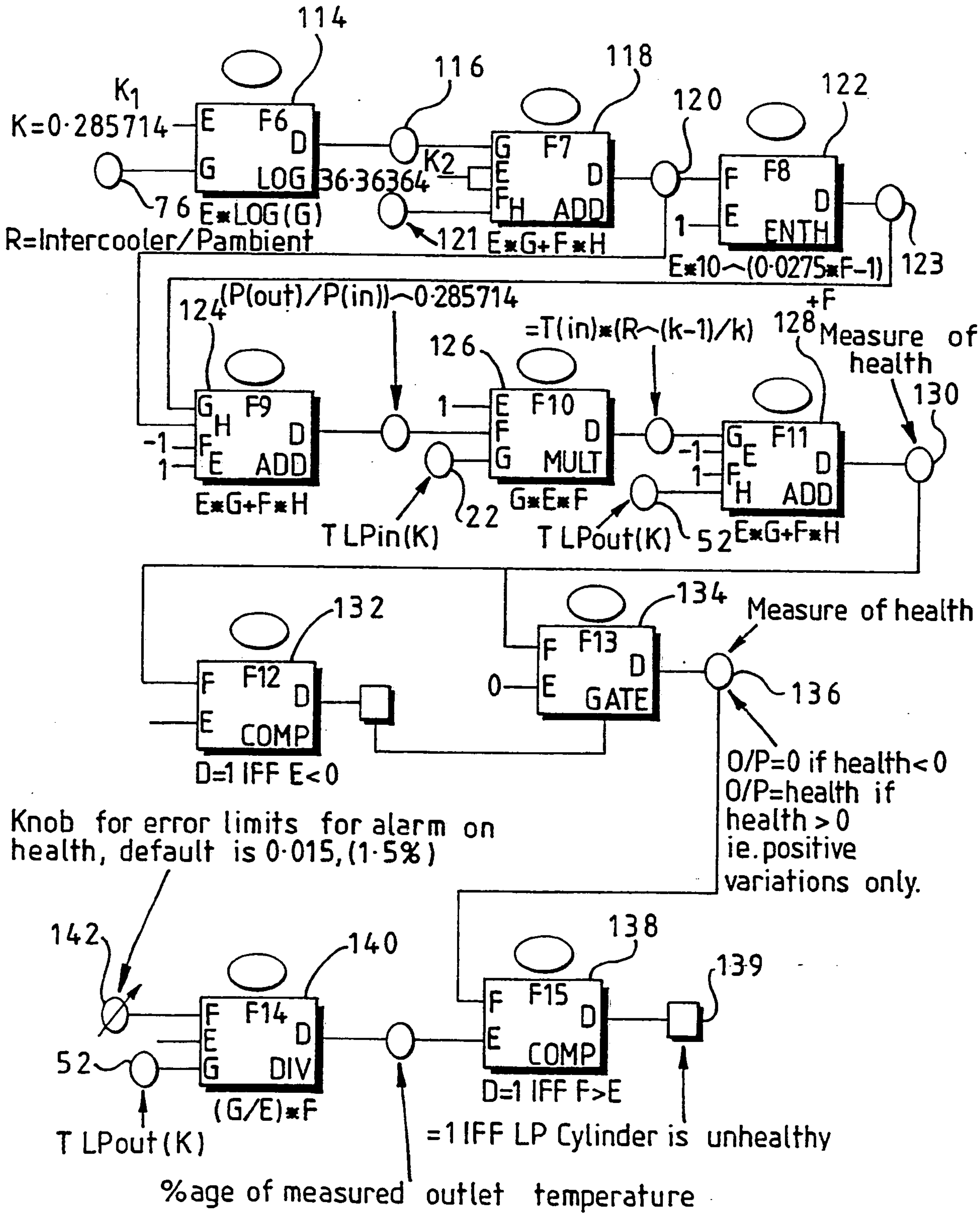

10
14
12
T LP in(DegC)
20
18
T LP in(K)
F1
D
ADD
16
22
E*G+F*H
40
T LPout (DegC)
48
T LPout(K)
50
F2
D
ADD
46
52
42
44
E*G+F*H
P Intercooler (Barg)
P Intercooler/P Ambient
60
64
66
76
62
65
67
F33
F3
D
DIV
P Discharge (Barg)
78
70
73
F34
D
ADD
74
75
68
(G/E)*F
72
E*G+F*H
P Discharge/P intercooler
88
T HPin(DegC)
90
THPout (K)
F4
D
ADD
82
86
92
84
80
E*G+F*H
108
102
T HPout (DegC)
110
T HPout (K)
F5
D
ADD
106
112
104
100
E*G+F*H

FIG 1

FIG 2


114
116
118
120
122
K1
K=0·285714
E F6 D G LOG
76
E*LOG(G)
R=Intercooler/Pambient
36·36364
K2
G F7 E D F H ADD
121
E*G+F*H
F F8 E D ENTH
1
E*10~(0·0275*F-1)
123
124
(P(out)/P(in))~0·285714
G H F9 F D E ADD
-1
1
E*G+F*H
126
=T(in)*(R~(k-1)/k)
1
E F10 F D G MULT
G*E*F
T LPin(K)
22
128
+F
Measure of health
130
G E F11 F D H ADD
-1
1
T LPout(K)
52
E*G+F*H
132
F F12 D E COMP
D=1 IFF E<0
134
F F13 D E GATE
0
Measure of health
136
O/P=0 if health<0
O/P=health if health>0
ie. positive variations only.
Knob for error limits for alarm on health, default is 0·015, (1·5%)
142
140
F F14 E D G DIV
52
(G/E)*F
T LPout(K)
138
F F15 D E COMP
D=1 IFF F>E
139
=1 IFF LP Cylinder is unhealthy
%age of measured outlet temperature

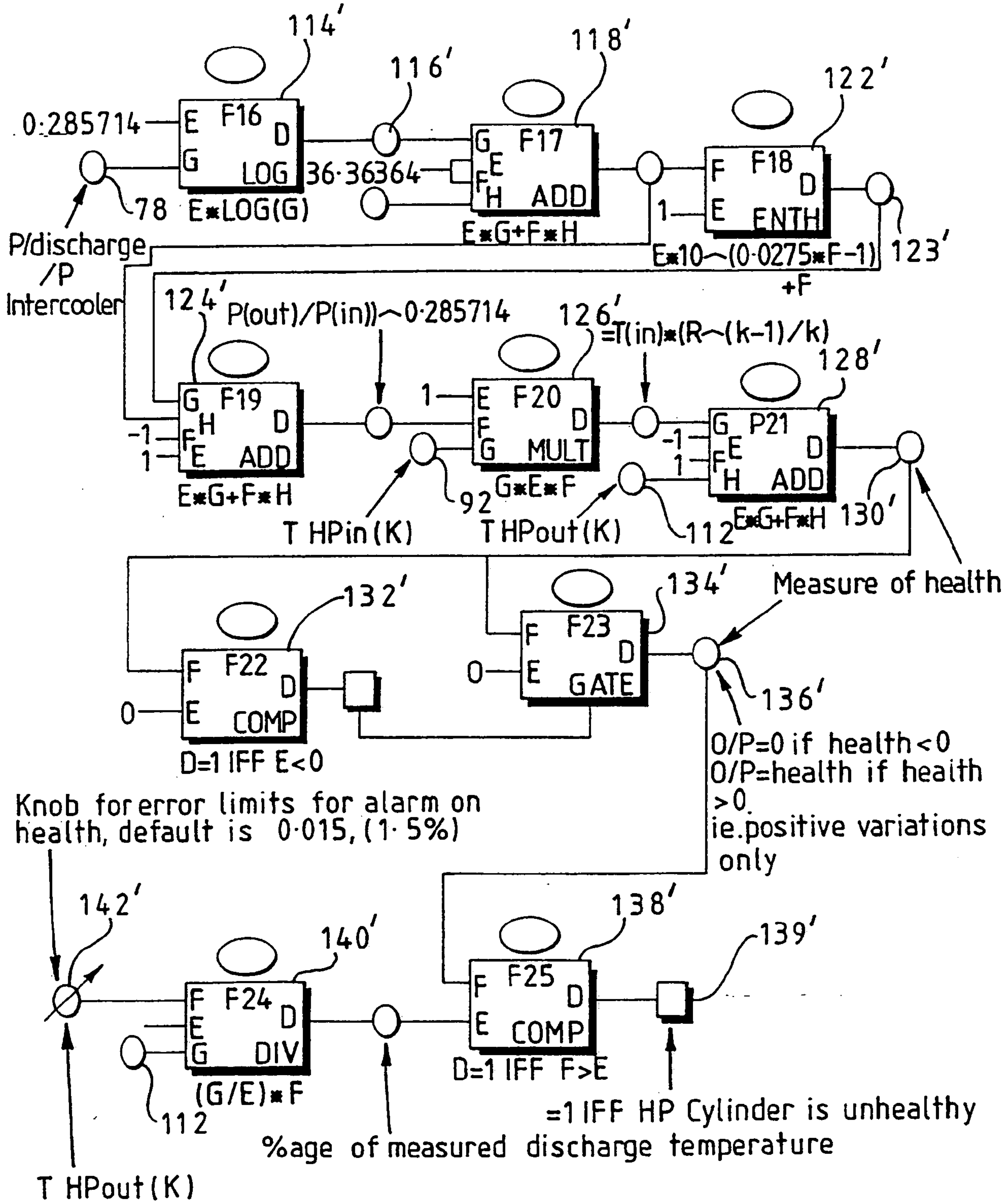

114'
116'
118'
122'
0·285714
F16
E
D
G
LOG
E*LOG(G)
78
P/discharge
/P
Intercooler
36·36364
F17
G
E
F
H
ADD
E*G+F*H
F18
F
D
1
E
ENTH
E*10~(0·0275*F-1)
+F
123'
124'
P(out)/P(in))~0·285714
126'
=T(in)*(R~(k-1)/k)
128'
F19
G
H
D
-1
F
1
E
ADD
E*G+F*H
1
F20
E
F
D
G
MULT
G*E*F
92
T HPin (K)
T HPout (K)
112
P21
G
-1
E
D
1
F
H
ADD
E*G+F*H
130'
132'
134'
Measure of health
F22
F
D
0
E
COMP
D=1 IFF E<0
F23
F
D
0
E
GATE
136'
O/P=0 if health<0
O/P=health if health
>0
ie.positive variations
only
Knob for error limits for alarm on
health, default is 0·015, (1·5%)
142'
140'
138'
139'
F24
F
D
E
G
DIV
(G/E)*F
112
F25
F
D
E
COMP
D=1 IFF F>E
=1 IFF HP Cylinder is unhealthy
%age of measured discharge temperature
T HPout (K)

FIG 3

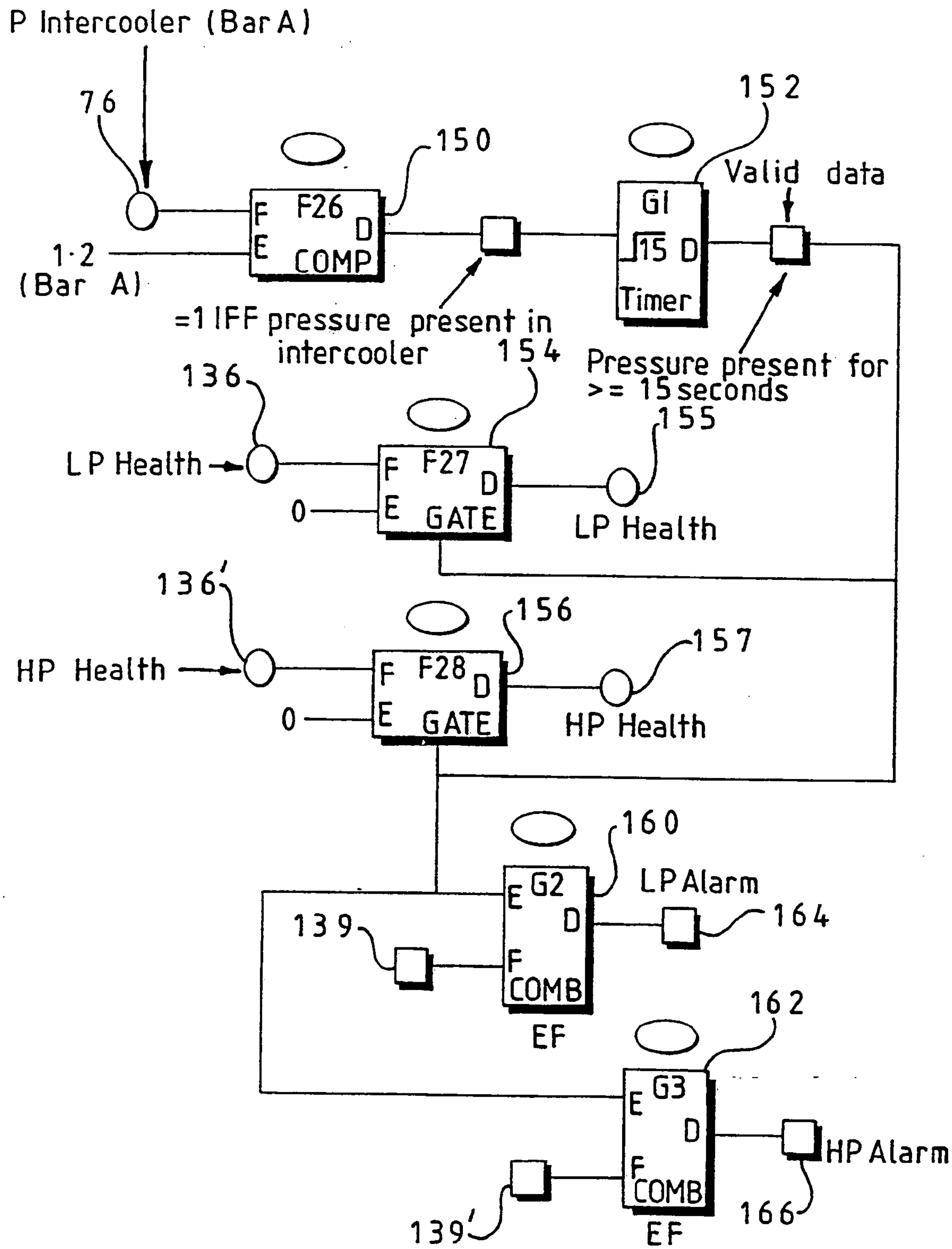

P Intercooler (Bar A)
76
150
152
Valid data
F
E
F26
D
COMP
1·2
(Bar A)
GI
15 D
Timer
=1 IFF pressure present in intercooler
154
Pressure present for
>= 15 seconds
136
155
LP Health
F
E
F27
D
GATE
0
LP Health
136'
156
157
HP Health
F
E
F28
D
GATE
0
HP Health
160
E
G2
D
F
COMB
LP Alarm
139
164
EF
162
E
G3
D
F
COMB
HP Alarm
139'
166
EF

FIG 4

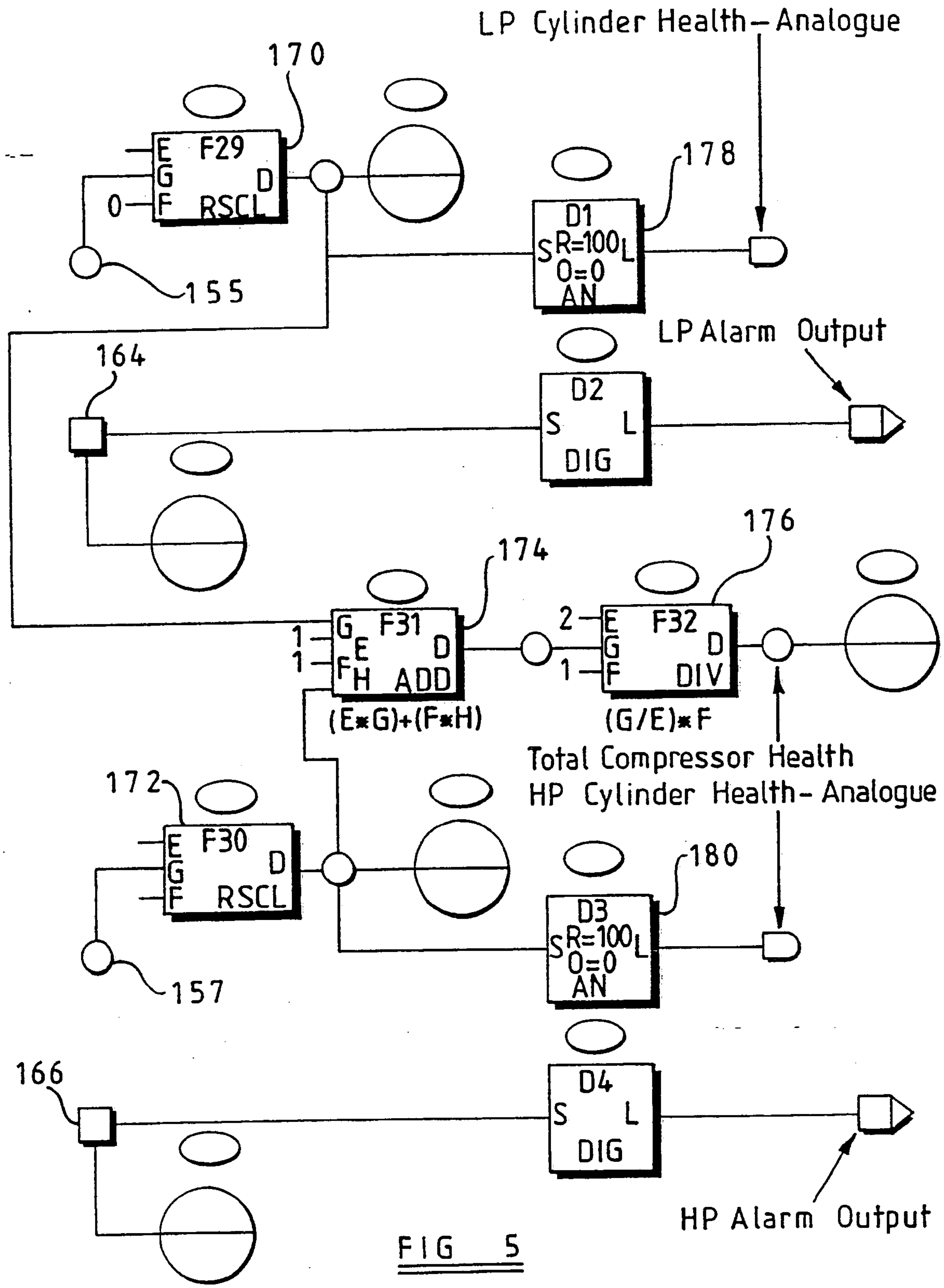

LP Cylinder Health - Analogue
170
F29
E
G
D
0
F
RSCL
178
D1
S
R=100
L
O=0
AN
155
LP Alarm Output
164
D2
S
L
DIG
176
174
G
F31
E
D
1
1
F
H
ADD
2
E
F32
G
D
1
F
DIV
(E*G)+(F*H)
(G/E)*F
Total Compressor Health
HP Cylinder Health - Analogue
172
E
F30
D
G
F
RSCL
180
D3
S
R=100
L
O=0
AN
157
166
D4
S
L
DIG
HP Alarm Output

FIG 5

2251492

Title: Compressor Monitoring System

The present invention relates to a system for monitoring an air compressor.

One of the difficulties associated with the use of air compressors is maintaining a check on the efficiency of the compressor during normal operation.

The present invention seeks to provide an improved system for monitoring operation of an air compressor.

Accordingly, the present invention provides a system for monitoring selected parameters of an air compressor having at least one cylinder comprising:

first sensing means for providing a first electrical temperature signal representative of the temperature of air drawn in to said cylinder;

second sensing means for providing a second electrical temperature signal representative of the temperature of pressurised air at an outlet of said cylinder immediately after compression by the compressor;

third sensing means for providing a first electrical pressure signal representative of the pressure of air output from said cylinder of the compressor; and

fourth means for receiving said electrical temperature and pressure signals and providing a first output signal as a predetermined function of said temperature and pressure signals for indicating the efficiency of operation of said cylinder of the compressor.

In a preferred form of the invention the temperature measurements

are taken at the input and output of a cylinder of the compressor.

Advantageously, a system according to the present invention also has fifth sensing means for providing an electrical signal representative of the pressure of air input to the compressor and said output signal of said fourth means is a predetermined function of all said electrical signals.

Where the compressor is a two stage compressor, a further preferred form of the invention has sensing means for providing an electrical signals representative of the temperatures at the inputs and outputs of both cylinders and the air pressure intermediate the two cylinders.

The present invention is further described hereinafter by way of example, with reference to the accompanying drawings, in which:

Figures 1 to 5 are schematic diagrams of various portions of a system according to the present invention for monitoring operation of a double cylinder air compressor.

Referring firstly to Figure 1, this shows five sensing circuits 10, 40, 60, 80 and 100 for sensing parameters of a two stage air compressor and providing output signals proportional to the value of the monitored parameters. In a two stage air compressor air is drawn into the first cylinder for compression, then passed to a second cylinder for further compression before being passed through an output of the compressor. In Figure 1, circuits 10, 40, 80 and 100 are identical and therefore only one of these circuits, circuit 10 is described in detail.

Circuit 10 has a temperature sensor 12 which measures the temperature immediately adjacent an air input to the first or low pressure cylinder of the compressor and the output from the sensor 12 is processed by a processing circuit 14 to provide an output signal which represents the measured temperatures in

degrees centigrade. This signal is stored in a store 16 and applied to one input H of a scaling circuit 18. The latter has further inputs E, F and G and a scaling reference value which is stored in a reference store 20 is applied to the input G. In this example the reference value is 273.15, whilst each of the other inputs E and F has a unitary value input.

The scaling circuit itself multiplies inputs E and G together and adds the resultant to the product of inputs F and H. The result is an output signal at output D which represents the value of the monitored temperature in absolute degrees kelvin, this being stored in an output store 22.

Circuit 40 is identical to circuit 10 and monitors the temperature immediately at the air output from the first cylinder of the compressor.

Circuits 80 and 100 perform the same functions as circuits 10 and 40 but whereas circuits 10 and 40 monitor the temperature of low pressure input and output air the circuits 80 and 100 monitor the temperature of the input and output air of the second or high pressure cylinder.

Referring now to circuit 60, this has two pressure sensors 62 and 70. The pressure sensor 62 monitors the intercooler air pressure i.e. the pressure between the two cylinders of the double cylinder compressor (or the output pressure of a single cylinder compressor) whilst pressure sensor 70 monitors the pressure of the air output from the compressor. The sensors measure gauge pressure and the signals from these pressure sensors 62 and 70 are operated on by processing circuits 64 and 72 to provide signals which are representative of the monitored pressures, these signals being stored in respective stored 66 and 74. Additional sealing circuits 61, 73 add one bar to the gauge pressure signals to convert these to absolute pressure values, the results being stored in stores 67, 75.

Ambient pressure is assumed to be one bar and therefore the value stored in store 66 is equivalent to the ratio of the monitored pressure to ambient pressure and is also transferred to a further store 76.

The outputs of the two stores 67 and 75 are applied to respective inputs E, G of a function generator 68 which divides the output from store 75 by the output from store 67 and multiplies the result by a reference signal applied to a further input F. In the described example, the reference signal is unitary and therefore the output of the function generator 68 is the ratio of the discharge pressure to the intercooler pressure and is stored in store 78.

Referring now to Figure 2, the intercooler pressure signal from store 76 is applied to one input G of a second function generator 114 which generates an output signal as a function of the input at input G and a reference value applied to a second input E. The reference value in the illustrated embodiment is a constant K_1 for adiabatic compression. The function generator 114 derives the logarithmic value of the pressure signal from store 76 and multiplies this value by the constant at input E to provide an output which is stored in store 116 and applied to one input G of a scaling circuit 118. A further signal is applied from store 121 to input H of the scaling circuit 118 whilst a second reference value is applied to two further inputs E and F. This reference value is constant K_2, the signals at inputs G and H each being multiplied by this constant and the resulting products being added together and applied to a further store 120.

The output from store 120 is applied both to one input F of a third function generator 122 and also to one input H of a further scaling circuit 124. A second input E of the function generator 122 receives a reference signal which in the illustrated embodiment is unitary. The function generator provides an output which is the following function of its input:

E*10^(0.0275*F-1)+F

The output of the function generator 122 is passed through a store 123 to input G of the scaling circuit 124. The latter also has inputs F and E to which reference signals -1 and 1 are respectively applied. The effect of the scaling circuit is to subtract the signal from store 123 from the signal received from the store 120, the different signal being fed to an input F of a multiplier circuit 126. The latter also has an input E to which a unitary signal is applied and an input G to which the temperature signal from store 22 is applied. The multiplier circuit 126 multiplies the three inputs together and applies the product to an input G of a further scaling circuit 128. This signal is subtracted from the signal stored in store 52 which is applied to a second input H of the scaling circuit, the difference being stored in a store 130. This signal is a measure of the efficiency or "health" of the low pressure cylinder of the compressor and is compared in a comparator 132 with a reference value which is zero. The comparator 132 in turn controls a gate 134 to prevent or allow the signal from store 130 to pass through the gate 134 to a further store 136. The comparator 132 and the gate 134 allow only positive variations of the signal in store 130 to pass through the gate to store 136.

The positively varying signal store 136 is applied to one input F of a comparator 138 to whose other input E is applied an error signal representative of the variation allowed in the signal from store 136 for a "healthy" cylinder. The error signal is derived from a function generator 140 which has a first input G to which the temperature value signal in store 52 is applied and a second input E to which a constant reference value is applied. In this particular case the reference value is 100 and the function generator 140 divides the signal at input G by the signal at input E. The resulting value is multiplied by a further variable reference value 142 which is applied to a third input F of the function generator 140. This further value is determined by trial and error and varies from compressor to compressor. A

typical value would be .015 and the resulting output signal of the function generator 140 is a percentage value of the temperature monitored by the sensor 12.

The comparator 138 compares the signal from the function generator 140 with the signal from the store 136, as it varies during operation of the compressor and provides an output signal to a store 139 which is logic 1 if the value of the signal from store 136 is greater than that from the function generator 40.

For the dual stage compressor having a low pressure cylinder and high pressure cylinder, the circuit of Figure 2 is duplicated for the high pressure cylinder with the exceptions described below, and as shown in Figure 3.

In Figure 3, input G of the function generator 114′ receives the pressure signal from store 78. The high pressure cylinder input temperature signal stored in store 92 is applied to input G of function generator 126′. The output temperature signal stored in store 112 is applied to input H of the scaler 128′ and also to input G of the function generator 140′. The circuit of Figure 3 operates in a similar manner to that of Figure 2 and the resultant output from comparator 138′ is a logic 1 signal if the high pressure cylinder of the compressor is not operating correctly.

The above described monitoring system operates effectively whilst the compressor is operating on full load. However, with a dual stage compressor it is possible for the compressor to operate at partial load during a cycle. If the compressor is operating on full load then the intercooler pressure between the two cylinders will be greater than 1.2 bar and will be maintained above this pressure for a minimum of a predetermined time which in the described embodiment is 15 seconds.

Referring now to Figure 4, the pressure ratio signal stored in store 76 is applied to a comparator 150 for comparison with a

preset reference value which in this example is representative of a pressure of 1.2 bar. The output of the comparator is a logic 1 signal if the signal from store 76 is greater than the reference value and is applied to a timer circuit 152 which applies an output signal to each of gates 154 and 156 when the output of the comparator 150 is at logic 1 for 15 seconds or more. The signal from the timer opens each of the gates 154, 156 to allow the health signals from stores 136, 136′ to pass, the signal also being applied to input E of each of two AND gates 160, 162. The output from comparator 138 is also applied to a second input F of AND gate 160 whilst the output from comparator 138′ is applied to a second input F of AND gate 162.

The output of gate 160 is connected to an alarm 164 for the low pressure cylinder whilst the output of gate 162 is connected to an alarm 166 for the high pressure cylinder. As a result, when the output of comparator 138, 138′ indicates a variation in the monitored temperature outside normal limits and the output of timer 152 indicates that the compressor is operating under full load then the associated gate 160, 162 triggers the respective alarm to indicate that either or both of the stages of the compressor require attention. The alarms can be either audio or visual or a combination of both.

The outputs of the two gates 154, 156 are also applied through stores 155, 157 to respective inputs G of scaling circuits 170, 172 (Figure 5). Each scaling circuit provides an output which is representative of the input signal as a percentage of a fixed reference value applied to a second input E. The outputs of the two scaling circuits are then applied to respective inputs of a summing circuit 174 which adds the two signals together, the sum then being divided by two in a divider circuit 176 to provide an output signal which is an indication of the "health" of the compressor unit as a whole. The outputs of the two scaling circuits 170, 172 are also applied to respective analogue circuits 178, 180 which provide output signals as analogue signals indicating the "health" of the low and high pressure

cylinders.

The above described circuit may also be used for compressors having only a single cylinder. In such a case only two temperature measurements are taken, these being the air inlet and outlet temperatures of the cylinder. In addition, the final discharge air pressure is measured and although not necessary, the air inlet pressure may also be measured. Furthermore, the circuit of Figure 3 is not required since this is merely a duplicate of the circuit of Figure 2 for the second cylinder of a dual cylinder compressor.

Claims

1. A system for monitoring selected parameters of an air compressor having at least one cylinder comprising:

first sensing means for providing a first electrical temperature signal representative of the temperature of air drawn in to said cylinder;

second sensing means for providing a second electrical temperature signal representative of the temperature of pressurised air at an outlet of said cylinder immediately after compression by the compressor;

third sensing means for providing a first electrical pressure signal representative of the pressure of air output from said cylinder of the compressor; and

fourth means for receiving said electrical temperature and pressure signals and providing a first output signal as a predetermined function of said temperature and pressure signals for indicating the efficiency of operation of said cylinder of the compressor.

2. A system as claimed in claim 1 wherein said fourth means comprises a first function generating means for generating a first function signal as a first predetermined function of said temperature and pressure signals and first comparing means for comparing said first function signal with a reference signal and generating said first output signal in dependence on said comparison.

3. A system as claimed in claim 2 wherein said comparing means comprises gate means coupled to an output of said first function generator means for receiving said first function signal, and a first comparator means operable to compare said first function signal with a reference value and open or close said gate means

in dependence on said comparison to provide said first output signal.

4. A system as claimed in claim 3 wherein said first comparator means is operable to open said gate in response to said first function signal exceeding said reference value in a positive direction.

5. A system as claimed in claim 2, 3 or 4 further comprising second comparing means for comparing said first output signal with a first error signal and generating a second output signal in dependence on said comparison.

6. A system as claimed in claim 5 wherein said second comparing means comprises second function generator means for generating said error signal as a second predetermined function of said second electrical temperature signal and a reference value, and second comparator means for comparing said first output signal with said error signal and generating said second output signal in dependence on said comparison for indicating the efficiency of operation of said cylinder.

7. A system as claimed in claim 6 wherein said reference value is adjustable.

8. A system as claimed in any of claims 1 to 7 wherein said air compressor is a double cylinder air compressor, said at least one cylinder is a first, low pressure cylinder and the second cylinder is a high pressure cylinder, further comprising:

fourth sensing means for providing a third electrical temperature signal representative of the temperature of air drawn into said second cylinder;

fifth sensing means for providing a fourth electrical temperature signal representative of the temperature of air at an outlet of said second cylinder immediately after compression by the

compressor;

sixth sensing means for providing a second electrical pressure signal representative of the pressure of air output from said second cylinder; and

fifth means for receiving said third and fourth electrical temperature signals and said second electrical pressure signal and providing a third output signal as a predetermined function of said third and fourth temperature signals and said second pressure signal for indicating the efficiency of operation of said high pressure cylinder;

and wherein said first output signal indicates the efficiency of operation of said first cylinder.

9. A system as claimed in claim 8 wherein said fifth means comprises a third function generating means for generating a second function signal as a third predetermined function of said third and fourth temperature and second pressure signals and third comparing means for comparing said second function signal with a reference signal and generating said third output signal in dependence on said comparison.

10. A system as claimed in claim 9 wherein said third comparing means comprises a gate means coupled to an output of said third function generator means for receiving said second function signal, and a third comparator means operable to compare said second function signal with a reference value and open or close said gate means in dependence on said comparison to provide said third output signal.

11. A system as claimed in claim 10 wherein said third comparator means is operable to open said gate means in response to said second function signal exceeding said reference value in a positive direction.

12. A system as claimed in claim 9, 10 or 11 further comprising fourth comparing means for comparing said third output signal with second error signal and generating a fourth output signal in dependence on said comparison.

13. A system as claimed in claim 12 wherein said fourth comparing means comprises fourth function generator means for generating said second error signal as a fourth predetermined function of said fourth electrical temperature signa and a reference value, and fourth comparator means for comparing said third output signal with said second error signal and generating said fourth output signal in dependence on said comparison for indicating the efficiency of operation of said second cylinder.

14. A system as claimed in claim 13 wherein said reference value is variable.

15. A system as claimed in claim 12, 13 or 14 further comprising fifth comparing means for comparing said first electrical pressure signal with a third reference value and providing a fifth output signal in response to said first electrical pressure signal exceeding said third reference value for a predetermined time period.

16. A system as claimed in claim 15 wherein said predetermined time period is 15 seconds.

17. A system as claimed in claim 15 or 16 wherein said fifth comparing means comprises a fifth comparator means for comparing said first electrical pressure signal and said reference value and a timer for generating said fifth output signal in response to said first electrical pressure signal exceeding said reference signal for said predetermined time period.

18. A system as claimed in claim 15, 16 or 17 further comprising third and fourth gate means for applying said second and fourth output signals to respective alarm means for each said cylinder,

and wherein each said gate means is operable in response to receipt of said fifth output signal to apply said second and fourth signals to said alarm means, thereby to generate an alarm signal in response to said second or fourth signal indicating a variation in monitored temperature outside normal limits.

19. A system as claimed in any of claims 15 to 18 further comprising respective scaling circuits for receiving said first and third output signals and generating fifth and sixth output signals as percentages of respective reference values, and means for averaging said fifth and sixth signals to provide an overall indication of the efficiency of the compressor, and wherein said first and third comparing means are coupled to said scaling circuits by way of respective gate means operable in response to receipt of said fifth output signal to apply said first and third output signals to said scaling circuits.

20. A system for monitoring selected parameters of an air compressor, substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

Application number: 9122732.2

Relevant Technical fields

(i) UK Cl (Edition K) G1N (NAAJ)

(ii) Int Cl (Edition 5) F04B 51/00; G01M 19/00

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner: M G CLARKE

Date of Search: 13 FEBRUARY 1992

Documents considered relevant following a search in respect of claims 1 TO 20

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
A	EP 0100210 A2 (Honeywell Inc) whole document	1
A	US 4584876 (ass. to Allied Inc) whole document	1

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family, corresponding document.

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).

Published 1992 at The Patent Office, Concept House, Cardiff Road, Newport, Gwent NP9 1RH. Further copies may be obtained from